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ABSTRACT

For several years, the University of Massachusetts has been developing a series of introductory-level mathematics courses which place primary emphasis on the development of problem solving and conceptual skills. As the need arose for more instructors for this course, an instructor-training program was developed. This report describes the development of classroom observation techniques that are used not only as a basis for program and teacher evaluation, but also as a device for in-service training. Instructors use these observation schedules, which focus on use of class time and patterns of teacher/student interaction, to observe and give feedback to one another. They were developed for use in workshop-style classrooms in which the instructor spends a majority of class time monitoring students as they work cooperatively in small groups. The courses in the Basic Math program, the teaching method, and the training program are described. (MNS)

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Evaluating and Modifying a Teaching Assistant Training Program for a Workshop-Style Mathematics Course

A Final Report

submitted to

The Fund for the Improvement of Postsecondary Education

Prepared by

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PROJECT OVERVIEW AND PURPOSE

For several years the University of Massachusetts has been developing a series of introductory-level mathematics courses which place primary emphasis on the development of problem solving and conceptual skills. As student demand for the courses increased, graduate students from a variety of departments at the University were recruited to serve as instructors. Given the non-traditional nature of the courses, and that many of the graduate students had had no prior teaching experience, an instructor training program was developed.

This report describes the development of classroom observation techniques that are now used not only as a basis for program and teacher evaluation, but also as a device for in-service training. Instructors use these observation schedules, which focus on use of class time and patterns of teacher/student interaction, to observe and give feedback to one another. While these observation techniques could be used for similar purposes in any classroom, they were developed for use in workshop-style classrooms in which the instructor spends a majority of class time monitoring students as they work cooperatively in small groups.

It was the question, "When and how should instructors intervene in a problem-solving group?" that we were most interested in exploring. Classroom observations led us to the conclusion that rather than seeing their role as asking the insightful, Socratic question, the instructor would do better to intervene in ways that encourage cooperation and interaction among students in the group. The "Socratic intervention" often left one member of the problem-solving group uninvolved in the interaction, thus undermining our emphasis on group processes. Our

Training program for instructors now includes careful viewing of videotapes of various instructors intervening with student diads. We focus the analysis of these episodes on verbal and non-verbal cues that instructors use to pomote interactions among the students.

In the following section, we describe in some detail the courses we teach, our teaching method, and the training program. Our aim is to provide enough information so that those interested in adopting some component of our program will have an idea of the context in which we have employed it.

BACKGROUND

The Basic Math Program at the University of Massachusetts consists of three main components. These included a) the math courses, b) an instructor training program, and c) an ongoing evaluation component. In this section we describe the math courses and the instructor training program; in the next section we describe the evaluation component, funds for the development of which were provided by FIPSE.

Remedial Math Courses

In the Sring of 1980, a report was submitted by the Special Committee on Remedial Mathematics at the University of Massachusetts, Amherst. The report summarized previous efforts to remediate entering students with deficient mathematical skills and made several recommendations based on a study of remedial programs at other state universities. At the time, students not prepared for calculus could take Math 104 or 104A--precalculus courses which covered algebra and

trigonometry in a rapidly paced, one-semester course. Students who felt unprepared for this course could take Math 011, a non-credit course which reviewed the essentials of elementary and intermediate algebra at a high-school level. The enrollements in this course for the Fall of 1979 and Spring of 1980 were 130 and 74, respectively. These numbers are not indicative of the number of students who needed a remedial course. First, since there was, at the time, no mathematics requirement for graduation, many students steered clear of college mathematics. Second, since Math 011 was non-credit, many who otherwise might have taken it opted instead to enroll in Math 104 or 104A.

Among the recommendations of the committee were that a new course be offered (Math 010) that reviewed arithmetic, elementary algebra and geometry, that non-graduation credit be awarded for Math 010 and 011, and that class size in these two courses be kept small.

Description of Courses

In the Fall of 1981, the Dean of Natural Science and Mathematics committed funds for the formation of a Basic Math Program, with the charge of developing and teaching new versions of Math 010 and 011. The courses that were developed (010L and 011L) differed from those taught previously by the Mathematics Department primarily by stressing problem solving and using a workshop-style of instruction rather than a lecture format. About 60% of class time in these new courses is devoted to students working in small groups on non-routine word problems. Early in the course, students are introduced to a procedure called "pair-problem solving" (cf. Whimbey & Lochhead, 1981). This procedure involves a pair

working together, alternating on successive word problems between being a "listener" and a "problem solver". Gradually, students are allowed to work together without these fixed roles, the hope being that they develop skills that will permit them both to take the initiative in working toward the solution of a problem, communicating clearly to a partner what it is they are doing, and to listen carefully but critically to their partner's ideas and solution steps. These conversations between partners promote student awareness of their own conceptualizations and reasoning processes as well as those of their peers. Thus, word problems are used not only for the development of mathematical concepts, but also for the development of more general problem-solving abilities. Related to the latter objective, we hope students come away from the course with the following notions of problem solving:

a) Solving a problem takes time.

b) Mathematical formula's and algorithms cannot be blindly applied.

c) Before solving a problem, it must be understood.

d) Errors in problem solving are common and must be expected.

e) For a particular problem there exist multiple methods of solution.

f) Once a solution is obtained, it must be checked.

The primary role of the instructor is to circulate among problem-solving groups, keeping them on task, listening carefully to the group to determine what difficulties they might be having, intervening in the group process when appropriate, and, in general, providing encouragement and feedback to the students. Instructors are trained, however, to resist temptations to explain to students how to solve a particular problem. An undergraduate teaching assistant who has

successfully completed Math 011L is assigned to each section of the course to aid the instructor, effectively doubling our teacher/student ratio.

In addition to in-class assistance, a help room has been set up which is staffed every day from 9 to 5:30. Students are encouraged to go there to study, to work with other students, and to get help when they need it.

A more detailed description of the courses, of the content, texts, and underlying philosophy are included in Appendix A.

Students

During the past three years Math 010L and 011L have served approximately 850 students, with class size averaging 25. Roughly half of the students taking the courses are freshmen with undeclared majors. Most of these have been advised to take one of the courses on the basis of their performance on a math placement test. Approximately a fourth of the students are enrolled in the School of Agriculture who are required to take the course or pass an exemption test. About one eight are psychology majors who, if they score poorly on a diagnostic administered by the Psychology Department, are required to take one of the courses as a prerequiste for a statistics course in Psychology.

Approximately 20% of the 4000 entering freshmen who take the math placement test each summer obtain scores that would place them in either Math 010 or 011. Thus we estimate that only about 30% of the students who have needed this level of mathematics have taken it. Some are still opting to take Math 104 to earn graduation credits. The majority of students, however, are probably avoiding college mathematics if their

majors do not require it. (A new General Education requirement goes into effect in the Fall 1986 semester that includes a minimal mathematical requirement for all students.)

As student demand for the courses increased, graduate students from a variety of departments at the University were recruited to serve as instructors. Given the non-traditional nature of the courses, and that many of the graduate students had had no prior teaching experience, an instructor training program was developed.

Summer Training Program

The training program for our instructors runs for 6 hours per day, for 20 days, and consists of workshops, discussion sessions, guest presenters, and classroom observations. The majority of this training involves active participation. Participants first learn how to solve problems working in pairs. Taking turns being the problem solver and the listener, they quickly come to appreciate the difficulties that their students will encounter in learning this technique. In addition, they deepen their own understanding of mathematics as they struggle with non-routine word problems.

Since a large percentage of time in our math courses is devoted to problem solving, the prospective teacher needs to develop appropriate monitoring and intervention skills. The most important of these is the ability to remain calm and provide a reassuring presence. If students are eventually to feel that failures and flounderings are a normal aspect of problem solving, the teacher must communicate a sense of well-being, especially when students are stuck and frustrated. When the teacher does intervene, it needs to be done in ways that promote student thought.

This is usually not accomplished by quickly pointing out student mistakes or by showing students a solution to the problem. Knowing how and when to intervene are not easily acquired skills, especially for those who are convinced that they know how to teach mathematics.

We have found that giving instructors training in how to conduct and analyze clinical interviews is especially well-suited for fostering the skills mentioned above. The clinical interview is used to explore thought processes that underlie problem solving--to develop models of the solver's mental representation of the problem (Konold & Well, 1981). Given this purpose, interventions by the interviewer are restricted primarily to probes that keep the subject talking or that require subjects to clarify their thoughts. Participants are first instructed in the purpose and method of clinical interviewing. Then, each participant conducts an hour-long interview with a student who has been recruited and paid to serve as a subject. Subjects are given several math word problems with the instruction to think aloud while they solve. The interviews are videotaped and are later reviewed and critically analyzed both by the interviewer and also by the group as a whole. With what they have learned from the first set of interviews, the process is repeated again using different subjects. It is in the process of conducting and analyzing these interviews that participants become convinced of the need to understand <u>why</u> a student makes a particular mistake before trying to correct the student. The need for a teacher to listen carefully is repeatedly rediscovered.

In addition to the above-mentioned training, participants read and discuss articles describing a) recent research in mathematical misconceptions (e.g., Davis, 1975; Clement, 1982); b) mathematical

foundations (e.g., Abbott, 1952; Davis & Hersch, 1981; Lakatos, 1976; Kline, 1980); c) educational philosophy and theory (e.g., von Glasersfeld, 1983; Novak, 1977), and d) applications of cognitive psychology and intellectual development to instruction (e.g., Koplowitz, 1978; Perry, 1970). During the final week of the program, participants observe and assist in a math course that employs our instructional techniques.

PROJECT DESCRIPTION

The major focus of the FIPSE project was to identify teacher behaviors that were related to desired student outcomes and then to develop a classroom observation technique that would allow the evaluation of those teacher behaviors. The original plan was to use this evaluation to identify areas of strengths and weaknesses in our instructors' performances, and then modify the Instructor Training Program accordingly. An additional goal of the project was to develop a catalogue of student misconceptions in arithmetic and introductory algebra that could be used as a teaching resource in similar courses. This catalogue is included in Appendix B.

The remainder of the report consists of a description of the teacher evaluation and program modification process.

Classroom Observation Schedules

To review, a major goal in our math courses is to train students to work cooperatively together on difficult word problems. In working cooperatively, students develop both the desired mathematical concepts as well as more general problem-solving abilities. Our first project task

was, then, to identify an observable set of desired students behaviors to which a corresponding set of instructor behaviors could be linked.

In the Spring of 1984 we began by making informal observations in sections of our courses. These observations were guided initially by prior work of Jane Stallings (1980) who has demonstrated that teachers alter the distribution of time spent on various class activities given appropriate feedback. We were also guided by prior distinctions among types of questions used by teachers and the characteristics of student responses elicited by such questions. Additionally, due to the nature of our particular classrooms, we were led to consider somewhat separately two general types of teacher behaviors: a) those that involve interactions with the class as a whole (Class Activity) such as lecturing, making assignments, defining and then getting students working on a task; and b) those behaviors related to interacting with individual students during problem solving (Teacher/student Interactions).

Class Activity Schedule

The Class Activity Schedule (see Appendix C) was designed to provide information on two fairly simple, but critical, aspects of the classroom: a) the way in which class time is distributed by the instructor among various activities, and b) the percent of students at any given time who are "on task". The observation schedule distinguishes among five types of class activity: administrative, lecture/discussion, problem solving, quiz taking, and undefined. The first two categories include all activities that the class engages in as a group, with the distinction being that "administrative" is not directly related to the content of the course, while "lecture/discussion" is. Making

announcements concerning test dates, homework assignments and due dates, and discussion of grading policies, would all be coded as administrative. Discussing problems students had on a test, introducing rational numbers, solving a problem together as a class, would all be coded as lecture/discussion. "Problem solving" is time devoted to students working on math problems in pairs or small groups. "Quiz taking" involves working individually on a quiz. "Undefined" is any period of time during which the class activity is unclear to the students or which is not devoted to any of the above categories. The class getting started late, or finishing early, accounts for most of the undefined periods, but it also includes periods at the end of an activity when the instructor has not specified what students ought to be doing.

The schedule is completed by noting in column A the current class activity at one-minute intervals. In addition, about every five minutes the coder estimated the percent of the students on task. This is done by observing each student who is clearly visible and making a quick judgment as to whether he or she is attending to the appropriate task. The total number of students observed is noted in column C, the number attending in column B.

Teacher/student Interaction Schedule

Since the majority of teacher/student interaction in our courses ideally occurs while students are problem solving, we chose to concentrate on interactions involving the teacher and problem-solving groups. We began with the assumption that the type of teacher intervention was the most critical determinant of successful and unsuccessful interventions. Accordingly, the first coding schedule

consisted of seven different types of teacher responses: asking a) specific or b) open-ended questions, c) observing, d) giving feedback, e) directing, f) demonstrating, and g) repeating or rephrasing.

This approach was eventually abandoned for two major reasons. First, it was very difficult to accurately code in the classroom such a variety of rapidly occuring behaviors. Second, since student responses were ignored, the data gave no direct indication of how involved the students were.

An informal observation that significantly influenced the type of behavior we chose eventually to code was the tendency of some instructors in intervening to interact with only one member of a problem-solving group. This left the other member(s) often staring off in space, neither attending to the ongoing conversation nor working independently on the problem. We formulated as a primary objective that instructors intervene in such a way that would maximize student/student interaction. Our approach prior to this time was less well defined, but emphasized teacher probes that helped students overcomed various misconceptions. This objective, we believe, unwittingly encouraged instructors to focus in on one member of a problem-solving group at the expense of the other(s). We came to view instructor interventions in a group as potentially disruptive to student interactions. To the extent that time was monopolized by the instructor, or that all interactions while the instructor was present occurred between students and the instructor, the intervention was potentially disruptive and non productive.

The observation schedule we developed aimed at characterizing the pattern of interactions among the students and the instructor while the instructor was present. The observer chooses a location from which the students and instructor are both clearly visible and audible. The

interaction is coded by noting the order and approximate duration of verbalizations. At the conclusion of an intervention, the observer has a record showing a) every change in speaker, b) occasions for which a speaker continued speaking uninterrupted for more than 3 seconds, and c) silent periods that continued for at least 3 seconds.

For example, the string

1,2,2,P,1,1,0,P,P,P,2,1

indicates that a statement by student 1 was followed directly by a statement by student 2. Three seconds later, student 2 was still speaking. The instructor (P) intervened and was followed by student 1 who continued talking for at least 3 seconds (but not more than 5 seconds). Then a silent period of between 3 and 5 seconds followed after which the instructor intervened and spoke for between 6 and 8 seconds. This was followed by short statements by student 2 and student 1.

The string of symbols for each individual intervention is entered into a file, and a program first transforms the data so that subject 1 is always the most talkative, and then summarizes the data in matrix form via a Flanders' Interaction Analysis (Amidan & Flanders, 1967). The matrix provides a fairly clear picture of the types of interactions that occur and do not occur while the instructor is present. Table 1 includes two examples of matrix summaries. The number in each cell of the matrix is the frequency of occurrence of that pair of elements in the data string. For example, in the top matrix, the cell in row 4, column 2 ($C_{4,2}$) indicates that there were a total of 8 instances in the data string where a "2" was followed by a "P". The bottom row provides an overall summary of the interaction. Of the 126 total coded instances, 47 (37%) involved the instructor speaking, 53 (42%) involved the most talkative student and 20 (16%) the least talkative student. About 4% of

Table 1. Matrix Summaries of Teacher/Student Interactions

FIRST \ SECOND	0	P	1	2	
0	3	2	1	0	
P	1	5	31	10	
1	1	32	13	6	
2	1	8	8	4	
	6 (.048)	47 (.373)	53 (.421)	20 (.159)	126

FIRST \ SECOND	0	P	1	2	
0	2	2	1	2	
P	0	3	8	5	
1	3	6	5	6	
2	2	5	7	2	
	7 (.119)	16 (.271)	21 (.356)	15 (.254)	59

the interaction consisted of silent periods lasting longer than 3 seconds.

The main diagonal gives an indication of the amount of the interaction during which one of the participants was speaking for an extended period (3 seconds or longer). In this case, student 1 appears to have been the only participant who was speaking for considerable periods uninterrupted (13/126). The instructor has only 5 such instances, and student 2 only 4. (The 4 may have consisted of one long comment lasting from 15 to 17 seconds, or it may have been 4 separate instances, each lasting for 3 to 5 seconds, or some other combination; this information is lost in the summary.)

The off-diagonal values provide information about interactions among the participants. Cells $C_{3,2}$ and $C_{2,3}$ summarize the interaction between the instructor and student 1. About 50% of the intervention (62/126) consisted of interactions between these two. Interactions between the instructor and student 2 (indicated in $C_{4,2}$ and $C_{2,4}$) were considerably less (18/126) Also, $C_{3,4}$ and $C_{4,3}$ indicated the interactions between the two students was relatively infrequent (14/126). The bottom matrix in Table 1 gives evidence of an intervention of a different type in which the interactions among the participants were more evenly distributed.

Training Instructors as Observers

The Class Activity Schedule and Teacher/student Interaction Schedule were developed prior to the Instructor Training Program in the Summer of 1984. Originally it had been our plan to use these schedules a) to provide feedback to and b) as the basis of an evaluation of instructors during the Fall, 1984 semester. We decided, in addition, to

use the observation technique as part of the instructor training process. Our experience with coding in sections of our courses led us to believe that taking an outside observer role could be valuable in fostering some of the teaching skills we regarded as important.

Near the end of the Instructor Training Program approximately three hours of coding training and related discussion were distributed over two days. Videotapes were made of an instructor interacting with students in one of our classrooms. These tapes were used to give trainees experience in using and interpreting the observation schedules. (Appendix C includes a list of coding instructions which are given to instructors.)

At the beginning of the Fall semester, each instructor visited a section of the course in company with an experienced coder (Konold). They practiced the use of both observation schedules by coding independently, comparing results, and discussing disagreements between their codings and those of the expert.

RESULTS OF CLASSROOM OBSERVATIONS

A total of 67 class visits was made during the Fall 1984. Forty of the visits were made by instructors, the other twenty seven by Konold. As soon after the visit as possible, the coder was to meet with the instructor and share and discuss the results of the coding. To make a summary of the data quickly available for that purpose, data from both observation schedules could be entered into a file, and summary analyses quickly generated.

Instructors also met individually with Konold twice during the semester during which time they discussed the results of the classroom observations. Overall summaries of observations made in their class were

made available for this purpose. At the end of the semester, before viewing the overall summaries, the instructors were asked to provide various estimates (as described below) that were used to evaluate the effectiveness of the feedback to instructors.

Class Activity

Table 2 is a summary of the distribution of class time and percent student attention in each category, averaged over the 10 instructors and 62 visits. (For five of the visits, the data record was not complete.)

Student Attention

The "entry count" row indicates the number of separate samplings of students' attention during the corresponding activity. The values for percent attending appear comparable for problem solving and lecturing, and seem fairly low during announcements. Pearson product-moment correlations were calculated between the average percent time spent and the average percent attending for each of the three activities. The correlation for announcements was $r = -.734$, indicating that the more time an instructor devoted to announcements, the less attention they received. The corresponding correlation for lecture was $r = -.424$ and for problem solving $r = -.142$. These values suggest that the duration of problem solving does not tend to influence the degree of on-task behavior--that students maintain a relatively stable and high amount of effort during problem solving. This is less so in the case of lecturing, attention falling off as more time is spent, this trend being even more severe during announcements.

ACTIVITY	A	L	P	Q	U
TIME					
Mean	8.7	13.3	57.6	17.6	2.7
SD	5.12	7.12	12.41	6.49	1.42
ATTENTION					
Mean	63.7	77.8	80.6		
SD	12.77	8.04	7.36		
Entry Count	24	83	175		

Table 2. Overall Summary of Class Activity (62 Classes Sampled)

Activity	A Observed	B Expert's Ideals	C Instructor's Ideals	D Instructor's Estimates
Administrative	8.9	3.3 (1.25)	4.2 (2.33)	6.5 (2.20)
Lecture/Discussion	14.7	17.3 (2.05)	18.7 (6.80)	16.0 (7.46)
Problem Solving	56.1	71.7 (2.36)	65.1 (6.85)	57.7 (8.32)
Quiz Taking	18.1	7.5 (0.41)	11.3 (2.05)	16.3 (3.59)
Undefined	2.6	0	1.5 (1.69)	4.1 (3.51)
N	67	3	10	10

Table 3. Observed, Ideal and Estimated Percents of Class Time Allocated to Class Activities

Distribution of Class Time

In order to evaluate the distribution of time among the various class activities, three "experts" were asked independently at the end of the semester to indicate the percent of time they thought ideally should be devoted to each activity. The average of these estimates along with their standard deviations are noted in column B of Table 3. Column A contain the observed values.

Comparing column A to B, the largest discrepancies occur in the problem-solving and quiz-taking categories. More time was devoted to quizzes than was thought ideal, and this seemed to take away from problem-solving time. The other observed values are close to the expert values.

At the end of the semester, instructors were asked a) to indicate the percent of class time that they thought should be allocated to each activity, and b) to estimate the percent time they actually spent in each activity. The means and SD's of these values for the ten instructors are included in Table 3 under columns C and D. This data indicates that instructors are spending more time in quizzes (18.1%) than they think they ought to be (11.3%) and that it is problem-solving time that suffers (65.1%, instructor ideal, compared to 56.1%, actual). Overall, however, instructors appear to be well aware of the amount of time they actually are spending in each activity, and these values are reasonably close to the ideal estimates generated by both instructors and experts.

Teacher/student Interactions

A total of 50 interventions with student diads and 18 interventions with student triads were coded during Fall 1984. Three levels of analysis were used to summarize the results of these interactions: a) individual interventions, b) individual interventions summed over each instructor, and c) overall performance summed over interventions and instructors. The first two levels were used to give feedback to instructors; the third was used to provide an overall picture of the nature of interactions in our classes. Table 4 includes the overall matrices for interventions with diads (top) and triads.

Overall Participation

It is encouraging in the case of interventions with diads that instructors were less talkative than the most talkative students (.357 vs. .417) However, looking at the 50 individual episodes, in only 30 of them was it the case that the instructor made fewer statements than student 1. This indicates that our instructors are frequently being more active in their interventions than we would hope. This trend appears more pronounced in the case of interventions with student triads. Here, instructors are almost as talkative as the three students combined (.433 vs. the sum of .311, .141 and .064). The percentage for the least talkative students is very low in the triad interventions (.064) and suggests that in triads, one of the students assumes a passive role.

Table 4. Summary of Instructor Interactions with Diads (top) and Triads (bottom). Fall, 1984.

First \ Second	0	P	1	2	
0	92 (0.021) 0.0403	58 (0.013) 0.0209	57 (0.017) 0.0339	18 (0.005) 0.0116	-cell frequency -cell mean (unweighted) -standard deviation
P	56 (0.013) 0.0192	378 (0.108) 0.0899	632 (0.168) 0.0699	231 (0.066) 0.0451	
1	51 (0.015) 0.0281	652 (0.177) 0.0679	549 (0.170) 0.1254	173 (0.059) 0.0590	
2	25 (0.008) 0.0183	219 (0.060) 0.0447	180 (0.063) 0.0628	146 (0.039) 0.0456	
	224 (0.056) 0.0804	1307 (0.357) 0.1232	1418 (0.417) 0.1194	568 (0.169) 0.0900	-column frequency -unweighted means -standard deviation

total 3517
N = 50

Key
0 = Silent
P = Instructor
1 = Most talkative student
2 = Least talkative student

First \ Second	0	P	1	2	3	
0	11 (0.009) 0.0140	15 (0.013) 0.0214	11 (0.010) 0.0185	0 (0.000) 0.0000	4 (0.004) 0.0092	-cell frequency -cell mean (unweighted) -standard deviation
P	19 (0.017) 0.0239	195 (0.174) 0.1110	174 (0.148) 0.0969	79 (0.067) 0.0335	32 (0.032) 0.0235	
1	8 (0.010) 0.0179	173 (0.144) 0.0674	121 (0.117) 0.0863	27 (0.024) 0.0249	13 (0.015) 0.0234	
2	3 (0.002) 0.0067	79 (0.067) 0.0275	27 (0.027) 0.0273	57 (0.048) 0.0324	6 (0.006) 0.0102	
3	2 (0.002) 0.0062	38 (0.043) 0.0336	11 (0.010) 0.0132	4 (0.003) 0.0001	9 (0.007) 0.0105	
	43 (0.040) 0.0436	500 (0.443) 0.0872	344 (0.311) 0.0622	167 (0.141) 0.0556	64 (0.064) 0.0412	-column frequency -unweighted means -standard deviation

total 1118
N = 18

Key
0 = Silent
P = Instructor
1 = Most talkative student
3 = Least talkative student

In order to further interpret the results, instructors and experts were asked to provide "ideal" values for instructor interventions with student diads. These values are shown along with the observed values and instructors' estimates in Table 5. The instructor ideals are fairly close to those of the experts, which evidences a concensus of what ought to be occuring, at a gross level, during instructor interventions. It is clear that instructors are doing more talking, and student 2 less talking, than is considered ideal. It is very encouraging, however, that instructors' estimates are so close to the observed values. Instructors seem well aware of the nature and degree of the discrepancy between what they are doing and what they would like to do.

Interaction Patterns

Table 6 contains obtained, estimated, and ideal values for four types of interaction patterns for interventions with diads. There is a good match between expert and instructor ideals, with the exception that experts, compared to the instructors, thought there ought to be a higher level of extended statements by students. Comparing the ideal values to actual, there are two large discrepancies. The amount of instructor interaction with students is double what is considered ideal, and the amount of student/student interaction is only a third of the ideal value. Instructors seem aware of the latter discrepancy, though they severely underestimate it. Instructors appear completely unaware of the discrepancy between actual and ideal values for instructor/student interactions.

Comparing results of intervention with diads to triads (Table 4) the interaction values appear similar, with even less interaction among students in traids.

Statements made by:	A Observed	B Expert's Ideal	C Instructor's Ideal	D Instructor's Estimates
Instructor	35.7	18.3 (8.49)	21.5 (8.67)	32.5 (11.67)
Most Talkative Student	41.7	41.7 (6.24)	44.0 (9.70)	42.5 (9.55)
Least Talkative Student	16.9	31.7 (2.36)	28.2 (7.22)	17.2 (4.19)
Silent Periods (≥3 Sec.)	5.6	8.3 (2.36)	6.3 (4.61)	7.8 (4.19)

Table 5. Summary of Overall Participation of Instructors and Student Diads

	A Observed	B Expert's Ideal	C Instructor's Ideal	D Instructor's Estimate
Instructor Interactions with Students	47.1	21.7 (8.5)	22.0 (10.85)	25.6 (10.91)
Student-Student Interactions	12.2	40.0 (8.16)	40.5 (14.63)	23.9 (9.65)
Instructor's Extended Statements	10.8	6.7 (2.36)	11.5 (4.5)	21.7 (7.07)
Student's Extended Statements	20.9	28.3 (6.24)	19.5 (6.10)	21.1 (8.09)

Table 6. Summary of Interaction Among Instructors and Student Diads

Types of Instructor Interventions

The above consists of a quantitative analysis of the flow of instructor interventions. In an attempt to explore the types of probes that instructors use during an intervention, several videotapes were made of various instructors working with student diads. Immediately after the videotape session, instructors viewed the tape and commented on their rational for intervening (and not intervening) at various times during the session. From an analysis of these videotapes, along with the instructors' stimulated recall, a hierarchy of intervention levels was constructed. According to this hierarchy, there are three levels of intervention with problem-solving groups. These correspond to three general instructional goals in our courses. Ultimately, we are interested in the development of mathematical concepts and of explicit awareness (meta-cognition) of problem solving techniques (see Level 3 in Figure 1). This goal, however, is achieved through actually solving problems. Therefore, the development of problem-solving skills (Level 2) is viewed as prerequisite for Level 3. Similarly, problem solving skills are fostered through the development of good communication skills in the context of working cooperatively on a problem (Level 1).

With this general hierarchy in mind, the instructor ought to intervene at the lowest necessary level. If the group process has broken down, the intervention should function to get the group working well. Level 1 is further broken down into four criteria (hierarchically arranged) for a successful group interaction. Within this level, the instructor ought to intervene, again, at the lowest necessary point.

Figure 1. Intervention Levels in Math Problem Solving

Level 3 Conceptual Development

- 3.3 Understanding of fundamental non-target math concepts
- 3.2 Understanding of target math concepts
- 3.1 Understanding of problem-solving methods and techniques

Level 2 Problem Solving Skills

- 2.4 Determine validity of arrived-at solution
- 2.3 Monitoring and evaluating execution
- 2.2 Looking for or have explicit solution plan
- 2.1 Understand the problem

Level 1 Group Process

- 1.4 Statements are comprehended by listener
- 1.3 Producing comprehensible statements
- 1.2 Interacting
- 1.1 Working on problem

The Teacher/student Interaction Schedule can be viewed, in the context of this model, as providing information primarily about Level 1 activity. To the extent that instructors dominate conversation during an intervention, and that student/student interactions occur infrequently, the group process is probably non-optimal.

SUMMARY AND CONCLUSIONS

During the course of this project, our approach to the general question of the characteristics of a good workshop instructor went through several revisions. We began with the belief that our instructors could be rank ordered in terms of effectiveness on the basis of some observable classroom behaviors. Having identified critical teacher behaviors, we could work to develop them in our training program. We soon discovered that we could not find a meaningful way to rank order instructors. Performance of students across different sections of the course was nearly equal, ruling our the possibility of simply identifying the effective instructors as those with higher student scores on common exams. Rank ordering of instructors by two of the staff supervisors not only resulted in quite different orderings, but neither ordering correlated with any of the objective classroom measures we had obtained. In retrospect this does not seem surprizing in that it replicates decades of research on teaching--it is hard to say what makes good teachers or even to identify who they are.

Abandoning this approach, we selected a few simple teacher behaviors that we had reason to believe were important and that teachers could, upon being made aware, easily modify. On the basis of this approach we made the following changes to our program:

1. We have redefined the major objective of instructors' interventions with problem-solving groups. Whereas we use to emphasize being able to understand a particular student's problems and finding ways to remediate them, we now put a priority on keeping students interacting with each other. We have added sessions to our Summer Training Program that train instructors to intervene in ways that do not disrupt, but encourage, interactions among students. In-service training now includes videotaping instructors' interventions and reviewing these tapes with the instructors.

2. During the first semester of teaching, all new instructors now spend one day each week in another instructor's class, both making informal observations and completing the observation schedules. Instructors have commented on the value of this activity and feel it even more beneficial than receiving the results of such observations made in their own class. It also helps to reinforce the view that we are involved cooperatively in the continual process of improving our teaching skills.

3. We have advocated even less use of lectures given our finding of declinging student attention over time. We encourage instructors to be well prepared and efficient with lectures and discussions, and to break up longer presentations into shorter segments, with student problem-solving sessions between. We have also made structural changes that keep quiz time to intended limits.

4. We have trained instuctors to monitor more regularly in their class the percent of students on task. It is easy for instructors during problem solving to rush from one group to another without taking a moment between to survey the overall activity. We also encourage instructors to

make certain that enough problems have been assigned in class so that no group can finish and be left without a defined task. We also discourage the use of student triads.

We have chosen to focus our efforts based on a fairly low-level analysis of teaching since our teachers are, for the most part, inexperienced, and because we are not clear ourselves about the important variables in a high-level analysis. While we have no formal evaluation of whether these changes have made a difference, our sense is that they have. We are particularly encouraged by the accuracy of the estimates instructors gave of their use of class time and interaction patterns with student problem-solving groups. During the Fall, 1986 semester, we will attempt a more detailed evaluation of the effectiveness of various components of our training program. Those interested in the results of this evaluation or in receiving more information concerning aspects of the project described here may write to Cliff Konold or Jack Lochhead at the below address:

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APPENDIX C

CLASS ACTIVITY SCHEDULE

AND

CODING INSTRUCTIONS

CLASS ACTIVITY SCHEDULE

Date_____
Class_____
Instructor_____
Enrolled_____
Coder_____

Time (min.)	Teacher Activity	Students - # Attending	# Observed	N Δ
0				
1				
2				
3				
4				
5				
6				
7				
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47				
48				
49				
50				

Comments

Present at beg. of class

Summary

Activity	Total Time	% Time
A-Administrative		
L/D-Lecture or Discussion		
P-Problem Solving		
Q-Quiz		
U-Undefined		

CLASS ACTIVITY SCHEDULE: CODING PROCEDURE

Find a seating location in the classroom that maximizes the number of student faces that can be seen. This will usually be toward the front and off to one side of the classroom.

The coding form divides the class period into 50, one-minute intervals. The class activity that was occuring during each interval is noted. When the activity changes during an interval, record the activity that took up the majority of that interval.

DESCRIPTION OF ACTIVITIES

Administrative. Activities that involve the entire class and are not directly related to course content are coded as administrative. Such activities include:

- Announcement of test dates
- Description of homework assignments
- Discussion of grading or other course policies
- Passing out course materials

Lecture/Discussion. Activities that involve the entire class and are related to course content are coded as lecture/discussion. Such activities include:

- Discussing problems students had on a quiz or test
- Introducing rational numbers
- Solving a problem together as a class
- Discussing problem solving techniques

Problem Solving. Problem Solving is time devoted to students working on math problems in pairs and/or small groups.

Quiz Taking. Quiz taking is time during which students are working individually on a quiz.

Undefined. Any time period during which the class activity is unclear to the students is coded as undefined. The class getting started late, or finishing early, accounts for most of the undefined periods, but it also includes periods at the end of an activity when the instructor has not specified what students ought to be doing. Asking a nearby student, "What is supposed to be happening right now?" is a good technique for determining whether the activity is defined or not.

Student Attention

About every five minutes, make an estimate of the percentage of students who are on-task--engaged in the on-going activity. This is done by observing each student who is clearly visible and by making a quick judgment as to whether he or she is attending at that moment to the task at hand. Making eye contact with the instructor during announcements and taking notes is evidence for attending. Staring off to some other part of the room, or doing work on a problem when they ought to be listening is good evidence that they are not attending.

The judgment about whether they are attending or not is to be made for the moment you looked at them though it may require a few seconds to make the judgment.

In order to get a representative sample, it is very important to begin sampling attention at pre-arranged times and in a pre-arranged order. The easiest way to do this is to begin sampling only on the minute (i.e., when the second hand is on the twelve) and to always start with the same student and proceed through the students in the same order every time. Make separate records of students judged attending and not attending and afterward record the observation as number attending and total number observed. Record these values alongside the time interval during which the observation was made.

Note that, by definition, attending estimates cannot be made during undefined periods. Also, do not code attention during quizzes. For problem solving, wait for about 3 minutes after the class has broken into groups to code for attention.

Teacher/Student Interaction: Coding Procedure

Since you need to be able to determine who is speaking, and for how long, position yourself close to the group and at an angle so that as many faces as possible are visible. If one of the members speaks softly, it is especially important to be able to see his or her face. If after coding for a short while, it seems difficult to make accurate determinations of who is speaking, stop the coding. While it is most desirable to code from the time the instructor intervenes until the end of the intervention, this is not essential. You can begin and end coding at any time.

Each speaker is assigned a coding symbol. The instructor speaking is coded as "P", silent periods as "0" and students speaking as "1", "2", "3". (Do not code an intervention if the group consists of more than 3 students.) The assigning of numbers to students is arbitrary, but should remain consistent throughout the coded intervention.

The interaction is coded by noting the order and approximate duration of verbalizations. At the conclusion of an intervention, you will have a record showing a) every change in speaker, b) occasions for which a speaker continued speaking uninterrupted for more than 3 seconds, and c) silent periods that continued for at least 3 seconds.

For example, the string

1,2,2,P,1,1,0,P,P,P,2,1

indicates that a statement by student 1 was followed directly by a statement by student 2. Three seconds later, student 2 was still speaking. The instructor (P) intervened and was followed by student 1 who continued talking for at least 3 seconds (but not more than 5 seconds). Then a silent period of between 3 and 5 seconds followed after which the instructor intervened and spoke for between 6 and 8 seconds. This was followed by short statements by student 2 and student 1.

Your record of interventions should include the instructor's name, date, and your name. Indicate separate intervention by drawing a line between them.